

# $\alpha_s$ at Zinnowitz 2004

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A review of measurements of  $\alpha_s$  is given, representing the status of April 2004. The results prove the energy dependence of  $\alpha_s$  and are in excellent agreement with the expectations of Quantum Chromodynamics, QCD. Evolving all results to the rest energy of the  $Z^0$  boson, the world average of  $\alpha_s(M_{Z^0})$  is determined from measurements which are based on QCD calculations in complete NNLO perturbation theory, giving

$$\alpha_s(M_{Z^0}) = 0.1182 \pm 0.0027 .$$

## 1. INTRODUCTION

The coupling constant of the Strong Interactions,  $\alpha_s$ , is one of the most fundamental parameters of nature which is to be determined by experiment. In this review, a summary of the most recent measurements of  $\alpha_s$  representing the status of April 2004 is given, providing another incremental update of a more complete and concise review [1] and of [2]. For a detailed introduction into the field and for an overview and definition of basic concepts, equations and references, the reader is referred to [1,2].

## 2. NEW RESULTS

New or updated measurements of  $\alpha_s$  are available from many classes of high energy particle reactions. In the following subsections, the respective results will be shortly reviewed.

### 2.1. Deep Inelastic Scattering (DIS)

New measurements of  $\alpha_s$  from inclusive jet cross sections in  $\gamma p$  interactions at HERA are available from the ZEUS collaboration [3]. Jet cross sections and values of  $\alpha_s$  are presented as a function of the jet transverse energy,  $E_T^{jet}$ , for jets with  $E_T^{jet} > 17$  GeV. The resulting values of  $\alpha_s(E_T^{jet})$ , based on NLO QCD calculations, are displayed in Figure 1. They are in good agree-

ment with the running of  $\alpha_s$ , as expected by QCD, and average to

$$\alpha_s(M_{Z^0}) = 0.1224 \begin{array}{ll} \pm 0.0001 & \text{(stat.)} \\ +0.0022 & \text{(exp.)} \\ -0.0019 & \\ +0.0054 & \text{(theo.),} \\ -0.0042 & \end{array} \quad (1)$$

if evolved to the energy scale of  $M_{Z^0}$  using the QCD  $\beta$  function in two-loop approximation, c.f. [1] Equation 7.

Averaging all measurements of  $\alpha_s$  from jet production at HERA, which were recently reviewed e.g. in [4], results in

$$\alpha_s(M_{Z^0}) = 0.120 \begin{array}{ll} \pm 0.002 & \text{(exp.)} \\ \pm 0.004 & \text{(theo.),} \end{array} \quad (2)$$

unchanged from the previous average [2].

An update of  $\alpha_s$  from measurements of polarized structure functions [5], now containing data from the HERMES experiment at the HERA collider, results in

$$\alpha_s(M_{Z^0}) = 0.113 \begin{array}{ll} \pm 0.004 & \text{(exp.)} \\ +0.009 & \text{(theo.),} \\ -0.006 & \end{array} \quad (3)$$

in NLO QCD.

A new global analysis using all available precision data of deep inelastic and related hard scattering processes includes recent measurements of structure functions from HERA and of the inclusive jet cross sections at the Tevatron [6]. After

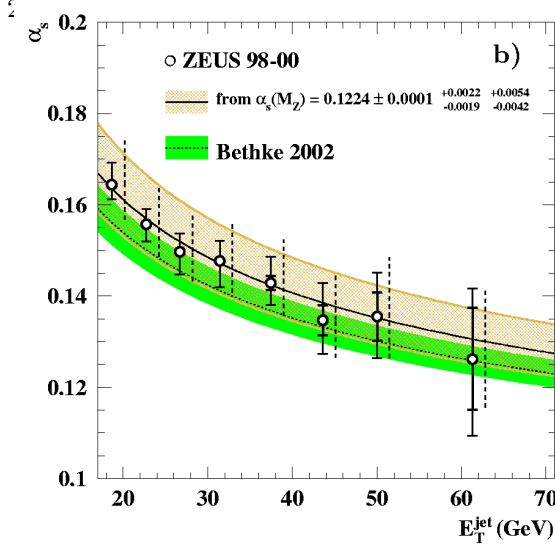


Figure 1.  $\alpha_s(E_T^{jet})$  values determined from QCD fits of the measured  $\frac{d\sigma}{dE_T^{jet}}$  from ZEUS [3]. The solid line corresponds to the central value of  $\alpha_s(M_{Z^0})$  determined in [3], the dashed line represents the world average [2].

analysis of experimental and theoretical uncertainties, and restrictions to “safe” fit intervals of the input distributions, the authors obtain

$$\alpha_s(M_{Z^0}) = 0.1165 \pm 0.002 \quad (\text{exp.}) \\ \pm 0.003 \quad (\text{theo.}), \quad (4)$$

in NLO QCD. Using NNLO QCD calculations wherever available, the same fit gives

$$\alpha_s(M_{Z^0}) = 0.1153 \pm 0.002 \quad (\text{exp.}) \\ \pm 0.003 \quad (\text{theo.}). \quad (5)$$

The latter result, however, does not relate to complete NNLO since predictions of jet production cross sections and parts of the DIS structure functions are only available in NLO so far. The previously obtained corresponding result,  $\alpha_s(M_{Z^0}) = 0.119 \pm 0.002 \pm 0.003$  [7], was derived without applying the new “safe” fit conditions.

## 2.2. $e^+e^-$ Annihilation

A recent summary of  $\alpha_s$  determinations from LEP, at the highest  $e^+e^-$  collision energies, and

from previous experiments at the PETRA and TRISTAN  $e^+e^-$  colliders was given in [8]. Apart from the results which were already discussed and presented in [1,2], updates on  $\alpha_s$  from electroweak precision measurements [9,10], from  $\tau$  lepton decays and from a recent combination of  $\alpha_s$  determinations from hadronic event shape observables and jet rates by the LEP QCD Working Group [11,12].

The most recent combination of the LEP-I and LEP-II electroweak precision measurements of all four experiments, in NNLO QCD, resulted in

$$\alpha_s(M_{Z^0}) = 0.1226 \pm 0.0038 \quad (\text{exp.}) \\ \begin{array}{ll} +0.0033 & (\text{M}_H) \\ -0.0000 & \\ +0.0028 & (\text{QCD}) \\ -0.0005 & \end{array} \quad (6)$$

from  $R_Z = \Gamma_{had}/\Gamma_\ell = 20.767 \pm 0.025$ , whereby the second error accounts for variations of the unknown Higgs boson mass between 100 and 900 GeV/ $c^2$ . The third error comes from a parametrisation of the unknown higher order QCD corrections, i.e. from variations of the QCD renormalisation scale and renormalisation scheme, see e.g. [1].

In the same analysis [10], the fitted leptonic pole cross section,  $\sigma_\ell^0 = (2.0003 \pm 0.0027)$  pb, resulted in

$$\alpha_s(M_{Z^0}) = 0.1183 \pm 0.0030 \quad (\text{exp.}) \\ \begin{array}{ll} +0.0026 & (\text{M}_H). \\ -0.0000 & \end{array} \quad (7)$$

Since  $\sigma_\ell^0 = \frac{12\pi}{M_Z^2} \frac{\Gamma_Z^2}{\Gamma_Z}$  and  $\Gamma_Z \sim \Gamma_{had}$ ,  $\sigma_\ell$  has a steeper dependence on  $\alpha_s$  than has  $\Gamma_{had}$ : in next-to-leading order, the QCD coefficient  $C_1$  for  $\Gamma_{had} \sim (1 + \sum_n (C_n \alpha_s^n))$ ,  $n = 1, 2, 3, \dots$ , turns to  $2C_1$  for  $\sigma_\ell$ ,  $C_2$  turns to  $(2C_2 + C_1^2)$  etc. The experimental error of  $\alpha_s$  from  $\sigma_\ell$  is thus smaller than that from  $\Gamma_{had}$ . However, with increased QCD-coefficients  $C_i$ , the renormalisation scale uncertainty also increases, c.f. Equation 13 of [1], such that the QCD uncertainty on  $\alpha_s$  from  $\sigma_\ell$  is expected to increase w.r.t.  $\alpha_s$  from  $R_Z$ .

A global fit of all LEP data to determine  $\alpha_s$  together with the masses of the  $Z^0$  boson, of the top-quark and of the Higgs boson, gives [10]

$$\alpha_s(M_{Z^0}) = 0.1200_{-0.0029}^{+0.0031} (\text{exp.}). \quad (8)$$

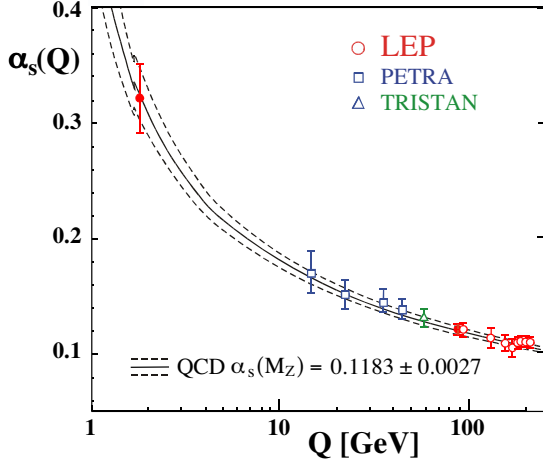


Figure 2. Summary of measurements of  $\alpha_s(Q^2)$  from electroweak precision measurements (filled symbols; in NNLO QCD) and from jet and event shape observables (open symbols; in resummed NLO QCD) in  $e^+e^-$  annihilation. The dashed curves represent the world average of  $\alpha_s(M_{Z^0})$  [8].

The latter result is the most precise available from combined electroweak fits of the LEP data.

Finally, using all available data from LEP, from SLC and from the Tevatron (i.e. including direct measurements of the masses of the top-quark and of the W-boson) results in

$$\alpha_s(M_{Z^0}) = 0.1186 \pm 0.0027 \text{ (exp.)} \quad (9)$$

For the latter two results, there is no additional uncertainty due to the unknown Higgs mass. The QCD uncertainties for these particular results of  $\alpha_s$ , however, were never determined, and prove to be difficult to be guessed due to the unknown size of the effective QCD coefficients that enter the overall fit. Similar as argued in the case of  $\sigma_\ell^0$ , the QCD uncertainty on  $\Gamma_{had}$  may be a good approximative estimate, but cannot simply be applied to other observables - especially if they are to be regarded as precision results.

The combined result of  $\alpha_s$  from  $\tau$ -decays, in NNLO QCD, is [8]

$$\alpha_s(M_\tau) = 0.322 \pm 0.005 \text{ (exp.)} \pm 0.030 \text{ (theo.)} \quad (10)$$

When extrapolated to the energy scale  $M_{Z^0}$ , this results in  $\alpha_s(M_{Z^0}) = 0.1180 \pm 0.0005(\text{exp.}) \pm 0.0030(\text{theo.})$ .

The overall combination of all LEP results on hadronic event shapes and jet production rates [12], using resummed NLO QCD predictions, results in

$$\alpha_s(M_{Z^0}) = 0.1202 \pm 0.0003 \text{ (stat.)} \pm 0.0049 \text{ (syst.)} \quad (11)$$

This analysis also provides precise values of  $\alpha_s$  in the c.m. energy range of LEP-I and LEP-II, from 91.2 to 206 GeV. These results, together with those from electroweak precision measurements and from  $\tau$  decays as given above and also including  $\alpha_s$  determinations from lower energy  $e^+e^-$  colliders, are summarised in Figure 2.

### 2.3. Hadron Colliders

Since the last update of this  $\alpha_s$  review [2], no new measurements of  $\alpha_s$  from hadron colliders were reported. In general, the available results from earlier studies, all in NLO QCD, are compatible with but not really competitive to those obtained from DIS and from  $e^+e^-$  annihilation. This is due to the sum of systematic uncertainties, from higher order QCD as well as from the available Monte Carlo generators, from underlying events and beam remnants, and from the energy calibration of detectors. Necessary improvements, like QCD predictions in NNLO and/or including resummation, corrections for nonperturbative effects, improved tools like new and more reliable jet algorithms, more data statistics and possibly more data at different collision energies are, however, underway and should be in place at the startup of the Large Hadron Collider.

## 3. SUMMARY AND WORLD AVERAGE

A summary of all significant measurements of  $\alpha_s$ , as discussed in [1,2] and with updates and new measurements presented in this review, is given in Table 1.

The values of  $\alpha_s(Q)$  are presented in Figure 3, as a function of the energy scale  $Q$  where the measurement was carried out. The data provide significant evidence for the running of  $\alpha_s$ , in good

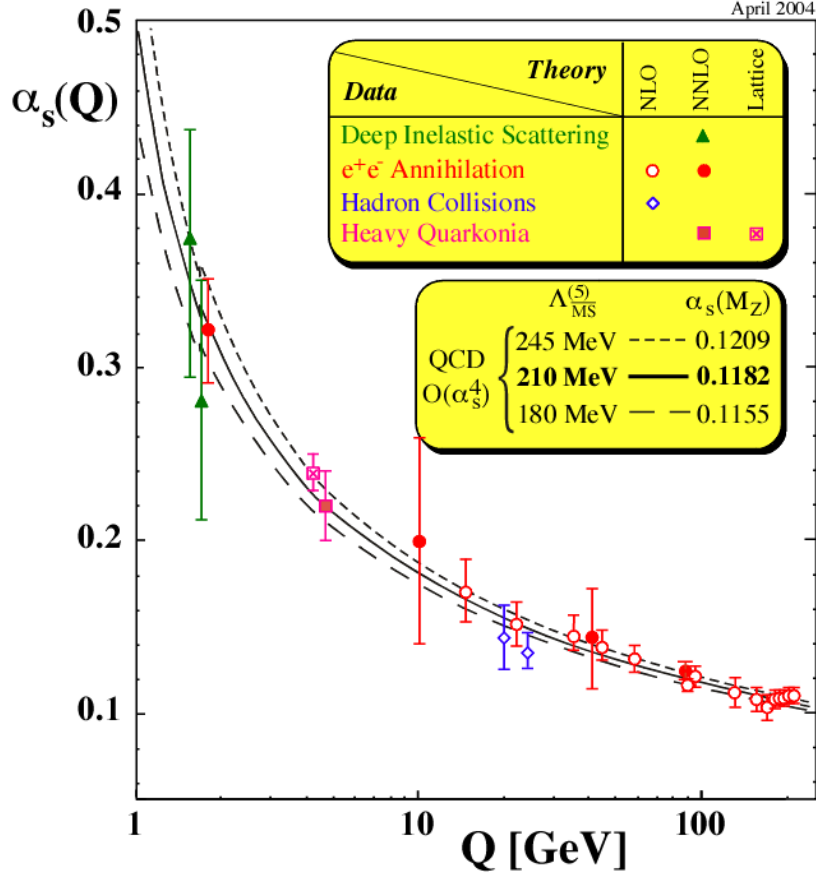


Figure 3. Summary of measurements of  $\alpha_s(Q^2)$ . Results which are based on fits of  $\alpha_s(M_{Z^0})$  to data in *ranges* of  $Q$ , assuming the QCD running of  $\alpha_s$ , are not shown here but are included in the overall summary of  $\alpha_s(M_{Z^0})$ , see Figure 4 and Table 1.

agreement with the QCD prediction.

Therefore it is appropriate to extrapolate all results of  $\alpha_s(Q)$  to a common value of energy, which is usually the rest energy of the  $Z^0$  boson,  $M_{Z^0}$ . As described in [1], the QCD evolution of  $\alpha_s$  with energy, using the full 4-loop expression [29] with 3-loop matching [30] at the pole masses of the charm- and the bottom-quark,  $M_c = 1.7 \text{ GeV}$  and  $M_b = 4.7 \text{ GeV}$ , is applied to all results of  $\alpha_s(Q)$  which were obtained at energy scales  $Q \neq M_{Z^0}$ .

The corresponding values of  $\alpha_s(M_{Z^0})$  are tabulated in the 4<sup>th</sup> column of Table 1; column 5 and 6 indicate the contributions of the experi-

mental and the theoretical uncertainties to the overall errors assigned to  $\alpha_s(M_{Z^0})$ . All values of  $\alpha_s(M_{Z^0})$  are graphically displayed in Figure 4. Within their individual uncertainties, there is perfect agreement between all results. This justifies to evaluate an overall world average value,  $\overline{\alpha_s}(M_{Z^0})$ . As discussed e.g. in [1], however, the combination of all these results to an overall average, and even more so for the overall uncertainty to be assigned to this average, is not trivial due to the supposedly large but unknown correlations between individual results, especially through common prejudices and biases within the theoretical calculations.

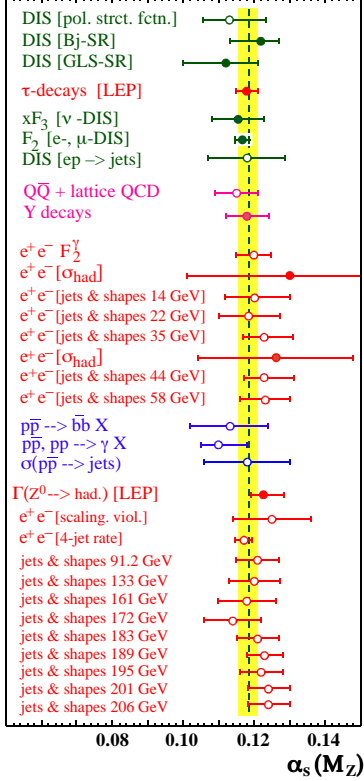


Figure 4. Summary of measurements of  $\alpha_s(M_{Z^0})$ . Filled symbols represent results based on complete NNLO QCD calculations.

For combining all or subsets of the results summarised in Table 1 into average values of  $\alpha_s(M_{Z^0})$ , the same procedures as utilised in [1] are being used. Averages  $\overline{\alpha_s}(M_{Z^0})$  for all and for subsets of  $\alpha_s$ -results, together with the corresponding uncertainties  $\Delta\overline{\alpha_s}$  are summarised in Table 2. As already discussed in [1], the overall uncertainties decrease if the averaging process is restricted to those which accomplished a minimum precision, i.e. a total error of  $\Delta\alpha_s \leq 0.008$ , while the value of  $\overline{\alpha_s}(M_{Z^0})$  is almost unaffected by such a restriction - c.f. rows 1 and 2.

There is a sufficiently large number of results which is based on complete NNLO QCD, such that  $\overline{\alpha_s}(M_{Z^0})$  can be reliably calculated from this subset (see rows 5 to 8 of Table 2). Due to the improved completeness of the perturbation series,

these results are believed to be more reliable and better defined than all the others which are complete to (resummed) NLO.

The world average of  $\alpha_s(M_{Z^0})$  is finally determined from those NNLO results that have total errors less than 0.008, namely

$$\begin{aligned} \text{DIS [Bj - SR]} : \quad \alpha_s(M_{Z^0}) &= 0.121^{+0.005}_{-0.009} , \\ \tau \text{ decays} : \quad \alpha_s(M_{Z^0}) &= 0.1180 \pm 0.0030 , \\ \text{DIS } [\nu, xF_3] : \quad \alpha_s(M_{Z^0}) &= 0.119^{+0.007}_{-0.006} , \\ \text{DIS } [e/\mu, xF_2] : \quad \alpha_s(M_{Z^0}) &= 0.1166 \pm 0.0022 , \\ \Upsilon \text{ decays} : \quad \alpha_s(M_{Z^0}) &= 0.118 \pm 0.006 , \\ \Gamma(Z \rightarrow \text{had}) : \quad \alpha_s(M_{Z^0}) &= 0.1226^{+0.0058}_{-0.0038} . \end{aligned}$$

For defining the overall total uncertainty, an “optimized correlation” error is calculated from the error covariance matrix, assuming an overall correlation factor between the total errors of all measurements. This factor is adjusted such that the overall  $\chi^2$  equals one per degree of freedom. This results in the new world average of

$$\overline{\alpha_s}(M_{Z^0}) = 0.1182 \pm 0.0027 , \quad (12)$$

c.f. row 6 of Table 2, which is practically identical to the final result of the previous summary [2],  $\overline{\alpha_s}(M_{Z^0}) = 0.1183 \pm 0.0027$ .

The choice of results which contribute to the determination of the world average value of  $\overline{\alpha_s}(M_{Z^0})$  is, similar as the calculation and definition of its overall uncertainty, arbitrary to a large degree. A matter of discussion sometimes is to include the overall fit result to the combined LEP electroweak precision data (Equation 8) instead of, as it is done here, using the result from  $R_Z$  (Equation 6), because the overall fit uses more information, the experimental error of  $\alpha_s$  is smaller, and there is no uncertainty on  $M_H$  in this case. With this replacement, and assuming the same QCD uncertainty as for  $\alpha_s$  from  $R_Z$  (which may not be appropriate, see the discussion in Section 2.2), results in  $\overline{\alpha_s}(M_{Z^0}) = 0.1180 \pm 0.0029$ . Replacing the result from Equation 6 with the one from Equation 9, i.e. with the world fit of electroweak data, gives  $\overline{\alpha_s}(M_{Z^0}) = 0.1177 \pm 0.0031$ . In both these cases,  $\overline{\alpha_s}(M_{Z^0})$  slightly decreases and the overall uncertainty increases, but fully within the assigned error. The slight increase of

$\Delta\overline{\alpha_s}$  is due to an increased correlation factor of 0.80 and 0.89, respectively, which is assumed to assure that the overall  $\chi^2$  is unity per degree of freedom. For reasons of clarity and of strict definitions of uncertainties, the usage of the result from  $R_Z$  (Equation 6) is preferred.

The world average of  $\overline{\alpha_s}(M_{Z^0}) = 0.1182 \pm 0.0027$  corresponds to the following values of the QCD scale  $\Lambda_{\overline{\text{MS}}}$  for different numbers of quark flavours  $N_f$ , evaluated using the full 4-loop expansion of  $\alpha_s$  and 3-loop matching at the quark thresholds (c.f. Equations 4 and 8 of [1]):

$$\Lambda_{\overline{\text{MS}}}^{N_f=5} = 210_{-30}^{+34} \text{ MeV} \quad (13)$$

$$\Lambda_{\overline{\text{MS}}}^{N_f=4} = 294_{-39}^{+41} \text{ MeV} . \quad (14)$$

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Table 1

World summary of measurements of  $\alpha_s$  (status of April 2004): DIS = deep inelastic scattering; GLS-SR = Gross-Llewellyn-Smith sum rule; Bj-SR = Bjorken sum rule; (N)NLO = (next-to-)next-to-leading order perturbation theory; LGT = lattice gauge theory; resum. = resummed NLO.

Process	Q [GeV]	$\alpha_s(Q)$	$\alpha_s(M_{Z^0})$	$\Delta\alpha_s(M_{Z^0})$		Theory	refs.
				exp.	theor.		
DIS [pol. SF]	0.7 - 8		$0.113 \pm^{+0.010}_{-0.008}$	$\pm 0.004$	$^{+0.009}_{-0.006}$	NLO	[5]
DIS [Bj-SR]	1.58	$0.375 \pm^{+0.062}_{-0.081}$	$0.121 \pm^{+0.005}_{-0.009}$	—	—	NNLO	[13]
DIS [GLS-SR]	1.73	$0.280 \pm^{+0.070}_{-0.068}$	$0.112 \pm^{+0.009}_{-0.012}$	$^{+0.008}_{-0.010}$	0.005	NNLO	[14]
$\tau$ -decays	1.78	$0.322 \pm 0.030$	$0.1180 \pm 0.0030$	0.0005	0.0030	NNLO	[8]
DIS [ $\nu$ ; xF <sub>3</sub> ]	2.8 - 11		$0.119 \pm^{+0.007}_{-0.006}$	0.005	$^{+0.005}_{-0.003}$	NNLO	[15]
DIS [ $e/\mu$ ; F <sub>2</sub> ]	1.9 - 15.2		$0.1166 \pm 0.0022$	0.0009	0.0020	NNLO	[16,2]
DIS [ $e$ -p $\rightarrow$ jets]	6 - 100		$0.120 \pm 0.005$	0.002	0.004	NLO	[17]
$Q\bar{Q}$ states	4.1	$0.239 \pm^{+0.012}_{-0.010}$	$0.121 \pm 0.003$	0.000	0.003	LGT	[18]
$\Upsilon$ decays	4.75	$0.217 \pm 0.021$	$0.118 \pm 0.006$	—	—	NNLO	[19]
$e^+e^-$ [ $F_2^\gamma$ ]	1.4 - 28		$0.1198 \pm^{+0.0044}_{-0.0054}$	0.0028	$^{+0.0034}_{-0.0046}$	NLO	[20]
$e^+e^-$ [ $\sigma_{\text{had}}$ ]	10.52	$0.20 \pm 0.06$	$0.130 \pm^{+0.021}_{-0.029}$	$^{+0.021}_{-0.029}$	0.002	NNLO	[21]
$e^+e^-$ [jets & shps]	14.0	$0.170 \pm^{+0.021}_{-0.017}$	$0.120 \pm^{+0.010}_{-0.008}$	0.002	$^{+0.009}_{-0.008}$	resum	[22]
$e^+e^-$ [jets & shps]	22.0	$0.151 \pm^{+0.015}_{-0.013}$	$0.118 \pm^{+0.009}_{-0.008}$	0.003	$^{+0.009}_{-0.007}$	resum	[22]
$e^+e^-$ [jets & shps]	35.0	$0.145 \pm^{+0.012}_{-0.007}$	$0.123 \pm^{+0.008}_{-0.006}$	0.002	$^{+0.008}_{-0.005}$	resum	[22]
$e^+e^-$ [ $\sigma_{\text{had}}$ ]	42.4	$0.144 \pm 0.029$	$0.126 \pm 0.022$	0.022	0.002	NNLO	[23,1]
$e^+e^-$ [jets & shps]	44.0	$0.139 \pm^{+0.011}_{-0.008}$	$0.123 \pm^{+0.008}_{-0.006}$	0.003	$^{+0.007}_{-0.005}$	resum	[22]
$e^+e^-$ [jets & shps]	58.0	$0.132 \pm 0.008$	$0.123 \pm 0.007$	0.003	0.007	resum	[24]
$p\bar{p} \rightarrow b\bar{b}X$	20.0	$0.145 \pm^{+0.018}_{-0.019}$	$0.113 \pm 0.011$	$^{+0.007}_{-0.006}$	$^{+0.008}_{-0.009}$	NLO	[25]
$p\bar{p}, pp \rightarrow \gamma X$	24.3	$0.135 \pm^{+0.012}_{-0.008}$	$0.110 \pm^{+0.008}_{-0.005}$	0.004	$^{+0.007}_{-0.003}$	NLO	[26]
$\sigma(p\bar{p} \rightarrow \text{jets})$	40 - 250		$0.118 \pm 0.012$	$^{+0.008}_{-0.010}$	$^{+0.009}_{-0.008}$	NLO	[27]
$e^+e^-$ [ $\Gamma(Z \rightarrow \text{had})$ ]	91.2	$0.1226 \pm^{+0.0058}_{-0.0038}$	$0.1226 \pm^{+0.0058}_{-0.0038}$	$\pm 0.0038$	$^{+0.0043}_{-0.0005}$	NNLO	[10]
$e^+e^-$ scal. viol.	14 - 91.2		$0.125 \pm 0.011$	$^{+0.006}_{-0.007}$	0.009	NLO	[1]
$e^+e^-$ 4-jet rate	91.2	$0.1170 \pm 0.0026$	$0.1170 \pm 0.0026$	0.0001	0.0026	NLO	[28]
$e^+e^-$ [jets & shps]	91.2	$0.121 \pm 0.006$	$0.121 \pm 0.006$	0.001	0.006	resum	[1]
$e^+e^-$ [jets & shps]	133	$0.113 \pm 0.008$	$0.120 \pm 0.007$	0.003	0.006	resum	[1]
$e^+e^-$ [jets & shps]	161	$0.109 \pm 0.007$	$0.118 \pm 0.008$	0.005	0.006	resum	[1]
$e^+e^-$ [jets & shps]	172	$0.104 \pm 0.007$	$0.114 \pm 0.008$	0.005	0.006	resum	[1]
$e^+e^-$ [jets & shps]	183	$0.109 \pm 0.005$	$0.121 \pm 0.006$	0.002	0.005	resum	[1]
$e^+e^-$ [jets & shps]	189	$0.109 \pm 0.004$	$0.121 \pm 0.005$	0.001	0.005	resum	[1]
$e^+e^-$ [jets & shps]	195	$0.109 \pm 0.005$	$0.122 \pm 0.006$	0.001	0.006	resum	[2]
$e^+e^-$ [jets & shps]	201	$0.110 \pm 0.005$	$0.124 \pm 0.006$	0.002	0.006	resum	[2]
$e^+e^-$ [jets & shps]	206	$0.110 \pm 0.005$	$0.124 \pm 0.006$	0.001	0.006	resum	[2]

Table 2

Average values of  $\overline{\alpha_s}(M_{Z^0})$  and averaged uncertainties, for several subsamples of the available data. The result printed in bold-face is taken as the new world average value of  $\overline{\alpha_s}(M_{Z^0})$ . “ $-F_2$ ” denotes omission of the result from  $F_2$  structure function fits [16].

row	sample (entries)	$\overline{\alpha_s}(M_{Z^0})$	opt. corr. $\Delta\overline{\alpha_s}$	overall correl.	uncorrel. $\Delta\overline{\alpha_s}$
1	all (32)	0.1190	0.0038	0.69	0.0009
2	” $\Delta\alpha_s \leq 0.008$ (23)	0.1192	0.0034	0.63	0.0010
3	all - $F_2$ (31)	0.1196	0.0043	0.71	0.0010
4	” $\Delta\alpha_s \leq 0.008$ (22)	0.1198	0.0039	0.68	0.0010
5	NNLO only (9)	0.1182	0.0031	0.68	0.0015
6	” $\Delta\alpha_s \leq 0.008$ (6)	<b>0.1182</b>	<b>0.0027</b>	0.61	0.0015
7	NNLO - $F_2$ (8)	0.1195	0.0042	0.75	0.0019
8	” $\Delta\alpha_s \leq 0.008$ (5)	0.1196	0.0038	0.74	0.0020
9	NLO only (23)	0.1197	0.0044	0.69	0.0011
10	” $\Delta\alpha_s \leq 0.008$ (17)	0.1199	0.0040	0.65	0.0012
11	DIS only (6)	0.1169	0.0033	0.76	0.0018
12	DIS - $F_2$ (5)	0.1185	0.0060	0.77	0.0031
13	$e^+e^-$ only (22)	0.1199	0.0044	0.77	0.0012